have the disadvantage of requiring frequent strengthening (concentration) of the brine.

Brine spray air washers for this type of work must have *special eliminators (with more bends than for water sprays)* in order to prevent excessive brine carryover. The air velocity through the washer should be from 500 to 750 fpm per sq ft of eliminator face area. The range of brine spray quantities varies *from 2 to 6 gpm per sq ft of cross-sectional area per spray bank.*

Some designs call for one spray bank, but most designs use two spray banks to secure the highest possible degree of saturation. The brine temperature range may vary from 2 to 10 F. *For ordinary calculations, the refrigeration ton capacity of a* brine system may be obtained by multiplying the gpm circulated by the brine temperature range and then dividing by 28 i.e., 28 gal deg (1 ton refrigeration). The air quantity usu*ally runs from 1000 to 1500 cfm per ton refrigeration.*

Calcium chloride or sodium chloride (salt) is used for brine, with sodium chloride most common in citrus work because of its cheapness. Both brines have a lower vapor pressure than water, and therefore have a drying effect on the air passing through the washer. Calcium brine has the lower vapor pressure and is the more drying. There may also be a precipitation of $CaCO_3$ from the carbon dioxide in the air. Salt brine will give fairly high saturation due to the high air-brine ratio and the low sodium chloride concentration required. It is not possible to obtain complete saturation when dehumidifying, especially with a brine spray, but it can be assumed to be about 95 percent rh for the air leaving a two-bank washer. Corrosion must be carefully guarded against with a washer system and, consequently, a pH value (hydrogen ion concentration) between 7.5 and 8.5 (a pH of 7.0 indicates a neutral brine) should be maintained for best results.

The refrigerant most commonly used in orange precooling work is ammonia. However, ammonia fumes are very injurious to citrus fruits, and precautions must be taken to eliminate leaks. It is most desirable to locate the ammonia compressors and all ammonia-containing vessels in a separate room or building, tightly closed off from the storage space. Refrigerant 12 is a safer refrigerant to use for unitary systems with separate conditioners in each room, as this refrigerant is not injurious to the fruit. An indirect system using calcium chloride brine for the cooling units located in the precooler rooms makes the best unitary system when ammonia is the refrigerant. With a central air washer, the brine may be cooled in a separate shell-and-tube brine cooler, or by direct expansion coils placed between the sprays in the air washer. Normally the refrigeration machine will be thermostatically controlled from the brine temperature.

AIR DISTRIBUTION

The quantity of supply air should be based on 3000 cfm for each car undergoing precooling, *plus 1000 cfm* for each additional car in storage only. The temperature rise in the supply air should be small, about 6 to 8 F deg at the beginning to 2 or 3 F deg at the end of precooling. This temperature rise may be *determined mathematically by dividing the sensible heat loss* in Btu per hour by the product of pounds of supply air per hour and the specific heat (*see Example 1*).

The amount of outdoor air is that required to keep the carbon dioxide generated by respiration to the desired minimum concentration for best keeping qualities of the fruit. The difference between the supply air quantity and the outdoor air quantity is the return or recirculated air quantity.

Wooden, wood fiber, or masonry ducts are used in most cases instead of sheet metal which will sweat and rust in the temperature and humidity conditions of an orange precooling room. Smooth wooden supply ducts are ordinarily designed for a maximum velocity of 1500 fpm at the fan with velocities tapering off in the branches to 800 or 1000 fpm. For masonry ducts, lower velocities should be used, say 1200 fpm *maximum. Dampers should be easily adjustable with positions* marked for precooling and storage air quantities. Supply and return dampers should be connected so as to operate as a unit for each room. Damper areas should be based on not more *than 1000 fpm air velocity. Dampers are often made of wood.* Metal dampers and metal transformation pieces or guide vanes, where required, should be protected with a heavy coating of bitumastic paint.

In precooling rooms, full height supply and return ducts are often formed by false walls at opposite ends of the room. Openings are provided near the floor, and another set near the ceiling. Dampers or adjustable slides over the openings in the *supply chamber admit air to the room, and similar dampers* are provided in the return chamber at the opposite end of the room. The space over the corridor is often utilized for the main return duct. The boxes of oranges are stacked so that the bulge or crown leaves an air space in the direction of air flow from one end of the room to the other. Where practicable the ducts are run inside the refrigerated space to save insulation. Ducts which are not inside refrigerated rooms should be insulated with the equivalent of four inches of corkboard.

In the final analysis refrigeration for oranges is an air conditioning problem. In designing a plant, careful attention must be given to the following important factors: (1) air volumes, (2) air temperatures, (3) humidity, (4) ventilation, (5) air distribution, (6) flexibility, and (7) controls. Consideration of these factors, in the manner outlined in the text, should result in a properly designed refrigeration plant.

LOAD CALCULATIONS

The heat gain through the exposed walls, floor and ceiling of the precooling of storage room is figured in the same manner *that any refrigerating or air conditioning load is calculated* from the exposed area, transmission coefficient and the temperature difference. Insulation should be four inches of corkboard or other material having an equivalent insulating value. *The heat gain from leakage through the insulation,* infiltration, or outdoor air, fan motors, pump motors, etc. is calculated in the usual manner. To these heat gains must be added the cooling down load for the fruit precooled each day and the *respiration load for all the fruit held in storage. The fruit* and the boxes should be considered separately because the former has a specific heat of 0.9 and the latter only 0.4. About 90 percent of the cooling down load will be sensible heat and the re*maining 10 percent latent heat. Example 1 gives* typical calculations for an orange precooling plant for five cars per day precooling capacity and 50 cars total storage capacity.

Example 1: Illustrate the calculations for a precooling plant *for oranges having space and capacity to handle* precooling of 5 cars of oranges per day. The maximum storage capacity is 50 carloads. The precooling time is 72 hr.

Solution. With three days allowed for precooling, maximum refrigeration load will occur with 15 cars undergoing precooling, five cars being loaded in, five cars being loaded out, and 25 cars in storage. Therefore, provide 10 rooms of five carloads capacity each for a maximum storage of 50 carloads.

Allow 240 sq ft floor area per carload. Boxes are stacked 3 high in precoolers. (5 cars) (240 sq ft) = 1200 sq ft floor area per room.

The floor space required for 5 cars will be 5 × 240 = 1200 sq ft.

Make rooms 20 × 60 × 10½ ft high, plus 5 ft for air ducts at ends, or 20 × 65 ft gross floor area. Insulation should be equivalent to 4 in. of corkboard. With 10 rooms, arranged five on each side of a 10 ft corridor, total refrigerated floor area will be approximately 100 × 140 ft = 14,000 sq ft. The cubic contents will be 14,000 × 10½ ft = 147,000 cu ft.

The computations are based on the following conditions:

Outdoor (Summer)	Conditions	Indoor
80(24-hr avg)	Dry-bulb temp, F	36
63	Wet-bulb temp, F	34.5
52	Dew-point temp, F	32
37	Relative humidity, %	85
57.6	Grains per lb	26.5
28.22	Btu per lb	12.81
13.78	Cu ft per lb	12.57

Sensible Heat Load	Btuh
(1) Heat transmitted through the surfaces. The room surface areas are: walls = 480 × 10½ = 5040 sq ft; floor: 140 × 100 = 14,000 sq ft; and ceiling: 140 × 100 = 14,000 sq ft.	
Walls (5040)(0.075)(80 − 36) =	16,000
Floor (14,000)(0.075)(80 − 36) =	46,200
Ceiling (14,000)(0.075)(80 − 38) =	46,200
Total Transmitted Heat	109,000
(2) Precooling fruit from 80 to 36 F in 5 cars of 462 boxes each with 74 lb of fruit per box. Cooling period is 24 hr. Specific heat is 0.09. Assume 90% of load to be sensible. $\frac{(5)(462)(74)(80-36)(0.09)(0.90)}{24}$ =	253,850
(3) Cooling boxes at 7 lb each and 0.40 sp ht. $\frac{(5)(462)(7)(80-36)(0.40)}{24}$ =	11,860
(4) Heat from respiration of 15 cars precooling at 58 F average temperature (see Table 5). $\frac{(15)(462)(74)(4700)}{(24)(2000)}$ =	50,200
(5) Holding 25 cars at 36 F. $\frac{(25)(462)(74)(1150)}{(24)(2000)}$ =	20,475
(6) Total Internal Room Load =	445,385
(7) Outdoor air: *10 cfm per car for 40 cars.* $\frac{(40)(10)(60)(0.24)(80-36)}{13.78}$ =	18,400
(8) Fan motor (25 hp *not in air stream*). 25 × 2545 = 63,625	
(9) Subtotal =	527,410
(10) Adding 5% *for duct and apparatus losses* =	26,665
Total Sensible Heat Load =	554,075

Latent Heat Load	Btuh
(1) Precooling 5 cars per day, assuming that 10% of load is latent heat. $\frac{(5)(462)(74)(80-36)(0.90)(0.10)}{24}$ =	28,200
(2) Respiration for 15 cars per day. See Table 5 and interpolate for 58 F average temperature. $\frac{(15)(462)(74)(323)}{(24)(2000)}$ =	3450
(3) Holding 25 cars at 36 F. $\frac{(25)(462)(74)(80)}{(24)(2000)}$ =	1430
(4) Outdoor air at 10 cfm per car. Load to be based on 40 cars. Moisture removal per pound of air *from* 57.6 to 26.5 gr. $\frac{(40)(10)(60)(57.6-26.5)(1060)}{(13.78)(7000)}$ =	8220
Total Latent Heat Load =	41,300

Table 5 .... Respiration Data for Citrus Fruits

(All factors are per 24 hr per 2000 lb of fruit)

	Temp, F	Sensible heat produced, Btu	Latent heat produced, Btu
Oranges	32	900	63
	40	1400	97
	60	5000	348
	80	8000	557
Lemons	32	580	40
	40	810	56
	60	2970	207
	80	6200	432
Grapefruit	32	460	32
	40	1070	74
	60	2770	193
	80	4180	291

Cooling Load Summary	
Total sensible heat =	554,075
Total latent heat =	41,300
Washer pump motor heat (20 hp) (20)(2545) =	50,900
Total Refrigeration Load =	646,275
=	53.9 Tons

Internal Sensible Heat Load for One Precooling Room at Five Carloads Capacity and Three Days to Precool	
Transmission through surfaces = (1/12)(109,000) =	10,900
Precooling = (1/5)(253,850) =	84,620
Cooling boxes = (1/5)(11,860) =	3,850
Respiration = (1/5)(50,200) =	16,730
Total	= 116,200

Internal Sensible Heat Load for One Storage Room of Five Carloads Capacity:	
Transmission through surfaces = (1/12)(109,000) =	10,900
Respiration = (1/5)(26,400) =	5,280
Total	= 16,180

Sensible Heat Gain from Fan and Duct System = 63,625 (Fan) + 26,665 (Ducts) = 90,290

Air Quantities and Temperatures

Base supply air quantity on 3000 cfm for each carload undergoing precooling plus 1000 cfm for each car in storage. Air quantity is to be based on 15 cars for precooling, 25 cars for storage and 40 cars total for outdoor air.

For precooling = (15 cars)(3000 cfm)	= 45,000 cfm
For storage = (25 cars)(1000 cfm)	= 25,000 cfm
Total supply air quantity	= 70,000 cfm
Outdoor air = (40 cars)(10 cfm)	= 400 cfm
Return air = Supply air − outdoor air	= 69,600 cfm